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166

## CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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#### LINER EXPANDER

This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

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Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38s, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

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Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49s are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

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fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein  $P_c$  is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 59 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1. A device for expanding a metallic liner inside a conduit which
  2 device comprises a shaft element, an expanding die member attached to said
  3 shaft element, said die member comprising a movable liner-forming member
  4 positioned on said shaft and being radially movable in respect thereof to
  5 contact said liner, an expander member slidably positioned on said shaft
  6 between said shaft and said die member to move said liner-forming member
  7 from said shaft, and a constant force spring member positioned on said shaft
  8 to contact said expander member and to maintain said expander member against
  9 said liner-forming member, whereby said liner-forming member is urged against
  10 said liner by a substantially constant force.
- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said 3 conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm 5 members disposed around said shaft and being pivotable outwardly therefrom to 6 contact said liner, a cone member slidably positioned on said shaft between 7 said shaft and said arm members to urge said arm members outwardly from said 8 shaft, and a constant force spring member positioned on said shaft to contact 9 said cone member and to maintain said cone member in contact with said arm 10 members, whereby said arm members are urged outwardly by a substantially 11 constant force.
  - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
  2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

  sleeve-like element connected to said movable bearing plate member and

  slidably positioned on said shaft and a member connected to said shaft to

  limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said chaft.
- 1 7. A device for installing an expanded metallic liner in a conduit 2 which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable out-5 wardly therefrom to contact the liner; a conical expanding member slidably 6 positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each 7 8 having a long rectangular cross-section and disposed circumferentially about 9 said shaft; an upper bearing plate member and a lower bearing plate member, 10 each slidably positioned on said shaft and contacting opposite ends of said 11 columns; limiting sleeves attached to each of said bearing plate members 12 and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply 13 14 a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the 15 axial travel of said bearing plate members is limited; said column members 16 . 17 transmitting their buckling load to said arm members to urge said arm members 18 outwardly with a substantially constant force.

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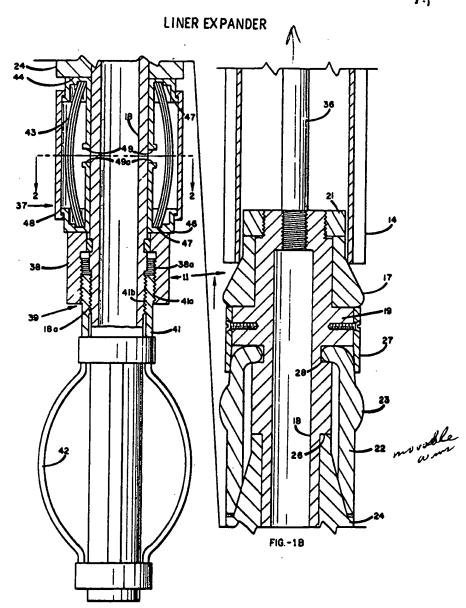
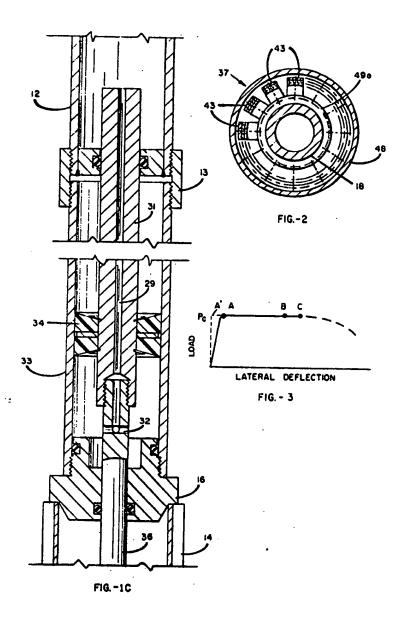


FIG.-1A



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2. A device for expending a setablic line; hashe a conduct which device comprison a shaft element, on expending the number obtained to said staff closents, still die meeter comprising a movelle liner-forming measur positioned on said that and being catally movelle in respect thereof to contact and liner, as expender moster aliably positioned on said shaft between said shaft and said the member to move said liner-forming meater from said shaft, and a constant force apring number positioned on said staff to contact said expenses member and to maintain said expenses member against said liner-forming member, sharely said liner-forming member is urged against said liner-forming member, startly said liner-forming member is urged against said liner by a substantially constant force.

2. In a ferrice for installing an expended setablic liner in a conduct wherein an expanding die is moved through a liner positional in said sometic to expend said liner: a cylindrical start element, an expanding die somber attached to said shaft, said the member comprising a plausitity of any mathers disposed around said shaft and being plottable enteartly therefore to contact said liner, a some member shidably positioned on said start between said shaft and said are members to very said are numbers colourely from said shaft, and a constant force spring number positioned on said staft to contact said once number in contact with said are members, whereby said are tembers are urged outwardly by a substantially constant force.

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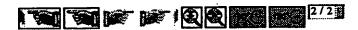
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- . A. The device of Claim 3 wherein said occurrention from comprises a differential surver equantity and agring number and said shaft.
- 5. The device of Claim 3 wherein sold step means comprises a alegra-like element somewhol to said wouddle bearing plate master and statistic positioned on said shaft and a sunday commuted to said shaft to limit the travel of said element.
- 6. The device of their 3 wherein sold columns have a machingdist cross-station, the width being greater than the Michiness, and bearing the wider fuce several to the dismotor of male shart.
- rice for installing an expended estallis liner to a conduct which comprises a cylindrical shaft classifi; on acquading dic senter sounted on mid shaft, said the member comprising a planning of are senters disposed ubially around the exterior of each shaft and budge plustable cutmaily therefrom to content the liner; a scalest expending preser slidely postthesed on smil short between smid shoft and maid are modern to urge said unity from said shaft; a plurelity of element columns, cash besing a long restangular cross-section and disposed circumterantially about said chaft; an upper bearing plate susher and a lower tearing plate scatter, such slikely positioned on said shaft and conducting appoints ands of said of limiting alseres obtained to senh of soid bearing plate numbers and alifably positioned an acid statts a aboulder amplet on such abaths a fifth-contrial acres showed commetting will shoulder and said shorts to apply thing look to onit columns; said thoulear being consecute with the eve semmeted to entil lenter bearing plate mester, whereby the arial travel of easi bearing plate members is limited; said column weathers transmitting their matting look to said are numbers to urge said are spaters esterrily with a entertantially communication.

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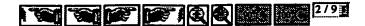
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curs, a mathod and apparetus have been developed for talling on experient as natte name as on tal roll or other contains Typically, a correspined steal liner is camerted in a conduct which is in be the greatest parishment-dissection of the liner being slightly less or of the contact. In expending tool is present ed to the contact, and a first-stone expanding the estic deformation of the liner, which is expended extremely the testile of the sembelt. A seagon-stage die on the tool then al finer deformation of the lines to provide a smoother, become the constant and the liker. In a typical design of this type ng tool, the frictional drug of the First-stage die sugplies the sking runes for the second-stage die, thick expending force is a direct function of the strength, or wall thickness, of the combit is which the r is being installed. For example, in himny oil well cusing, heavy s a very high trictional focus which results in excess e boding pagedred to youth the expender through the liner. The of the greek forcess required may result in replace of the carring ting the impailing tool. In testamen shore the interval. ath to monument team them there extended the results ore attack to the casing, or otherwise r spring errorgonant is employed in econocides with the s stign die, verloos difficulties are encountered in obtaining a spring sion having the desired strength is continution with the other springgries, and with the tool dragging against the furth will of the

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My invention will be better underwiced by reterents to the following description and the accompanying drawings wherein:

Piggree 3A, 18 and 10, below together, conviltute a partial sectional view of a preferred embediment of a liner expending tool according to the present investion; and

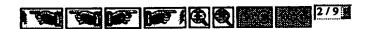




Figure 2 is a sectional where of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied loss versus believition for the constant force spring device of the Levention.

Referring to the drawings, Pigure 12 is the bottom portion of a liner expending tool for one in installing a motalile liner in a well, while Pigure 19 Libertrobes the middle section of such a took and Pigure 10 represents the upper section of the teal. The expending teat il is abtembed to ctassers well taking 15 by ampling 15 and, bypically, may be inserved from the murrace through a well easing (not shown) to a point in the sewing at which it ed to install a metallic liner. Before inserting the test into the well, an alongsted vertically corregated liner 18 fabricated from mild stand, or switchle mileshie meterial, is placed on the tool. The correspeted er is occurred in position by contact at its upper end with a cylindrical ther 16 and, at the lower and by contact with a first-stage expe ing die 17 in the form of a transmist circular core stich serves as a firstor becausefter described. The expanding die is stage expecting die in the sur fixedly ablacked to a controlly loanted, elemented sylintrical hollor shaft li which forms a portion of the body of the tool. As shown, the expending size 17 is half in place between a lawer shoulder 19 and coller 2) threaded outo the chaft. . A plurality of somple seem 45, preserably provided with outserelly cularged portions 25 mear the top, are disposed in the form of a splinder that's 16. The malarged portions of the arms 25 upon being moved outor into a substantially syllatrical shape. The are eashers 22 are plantally other 26 slikebly positioned on the shuft to corve as a s ir. The equipme of the master by, as shown, moves specially along the chart to engage with the eres and more than outwardly. Advantageously, the surfaces of the exps. 22 and the cutains curface of expending mechan 24 g sestions, typically ostegoed is shape. The outsi he controlled by the position of the master St rhich moves superally



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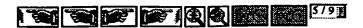
noti) it contants election for provided on the staft. As manker it women in a documently direction area 52 feld immunity towark the staft. The expending area 22 are held to place as the shaft by called 27 and circular grooms 20 provided on the shaft.

The expending tool, comprising the fluctuation of each the section rings die to drawn through the limit to expend in the plane in the casing. The first-stage die provides a gross deformation of the limit so that it is expended externily against the well of the sensing. The accord-stage die them passes through the limit and perfects the final expenden to smooth the inner section of the limit and to wrottle more even contact between the limit and

In operation, the liner setting tool is assembled at the surface, as described shows, and a glass cloth saturated with a revinces naterial may be and the corrugated take to farm the liner. The assembly is lowered all at the leastless of which the liner to to be set. A Liquid, such so cil, is then pusped under pressure down the well inking and flows through cogramy 29 provided to golished not 51, through ports 52 and into epitader 35 commeteted to the upper and of the shoulder 16. Upon the application of finid proviums to the optimier, the pietes 34 secured to polished rol 31 noves operally in cylinder 35. As shown, rot 36 cornects polished rot 31 and shaft on exist is mounted the first-stage expending die 17. When the piston A relly through the sylindar 35 the expending die 17 med the secondstage tie 22 are drive apparelly into the corrupted liner it and "iron out" stions in the liner, so that the expended liner may contact the familie well of the casing in which it is being installed. Positioned on the substantially sometant force. The force exacted against the emi soubers being to the sexing vill be unbetantially coordent so that either sticking ol in the casing or recture of the caring is precluded. Of source,



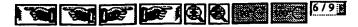
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forces between the toel and the liner and the pressure exerted against the eming are emintalized at predefermined safe levels. The constant force spring maker assures that the soutant pressure between the liner founding portion 25 of the sous 22 is great enough to provide the Scrized Scrizentian of the obs-

The equation's furne spring sampler 77 is alignity sounded on the shart 15 and hald between the expending alongst 25 and a sylinarical lower shoulder sampler 35 forming a portion of a differential screw alonest 39 which temperate the lossing on spring number 37 to shart member 18. The differential conversal comprises shart member 35 provided with funds the one was not a temple 15h, the lower shoulder member 35 provided with funds threads 55h and thinkle member \$1 provided with threads with threads and the statistic set threads are source, such as square, modified equark, or alone threads, to withertand very high loads and differ in pitch so that shoulder 35 is seven upwarfly on the shart 15 minn the shart 15 by splines \$5 so that it can slide longitudinally, but it is not tree to rotate on the shaft. Thusly stranged to the lower set of the thinkle is a friction member, such as but aprings \$2, a hydraulically equated friction pai, or other such device for frictionally engaging with the issues will of the samplet to occure the thinkle against transfer threads 35h, is the same as that of the shart threads 15h, a.g. righthend threads, and the pitch, or land, or around 15h is slightly greater than these of threads 35h, with the pitch rotate thinks 15h is slightly greater than these of threads 35h, with the pitch rotate thinks 15h is slightly greater than the of threads 35h, with the pitch rotate being alone to unity. In this summer, clock-vice revolution of the shart relative to the thinkle square threads on a chart approximately 1.7-inch outside dismeter and five and thready state approximately 1.7-inch outside dismeter and five and thready threads.





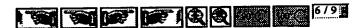
Constant force spring element 37 comprises estem element 33, expectageously consisting of a plurality of elongried columns disputed around shorts 18. Upper bearing plate senter th is in contact with the apper ends of the salume sed is elimbly positioned on shart 18 to trements the force of the spring longitudinally against the bottom end of expendes senter 26. Lover bearing plate number 16 confacts the lover sents of the columns and is soved specially along the sharts by lengthesians movement of boar shoulder 38 on a result of revolving differential serve element 39. Grooves 47 are provided in sents of the bearing plates, to form an upper race sed a lover race, into which the ends of the columns are inserted. These grooves may be shaped to contain with the shape of the nolumn onto it seatered. A cover 48 any be employed to amplify foreign matter from the spring mechanism such to protect

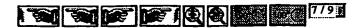
A name iter limiting the deflection of the columns to required.

Although the column element furctions in a backled condition, application of crossalive compressive load thereto would cause total failure or repture of the solumn. Therefore, a pair of stope to sea the terming plates, and, in affect comprise upper and loans limiting classes positioned on the sharf to alide longitudinally therem. The sude of the stope may move toward, or sample, each other so the load on the spring number vertex. Lower classes by in prevented from moding dams by loads shoulder 50 commented to the sharf 10.

Reserver, the spacing between the sade in much as to limit the longitudinal travel of the bearing plate masters as may move together to prevent permanent deformation of the column alament 53. Tarious alternative same for preventing damage to the column alament 53. Tarious alternative same for preventing seamed on the outent may across an applicated. For example, plus or rings seamed on the object may serve as stops, or the cover 48 provides of the switches of columns.

The columns of the column element 45 may be arranged erosed the chart 16, which as shown here there a portion of the body of the spring device, with made of the columns fitted in the runss 67. The columns may be

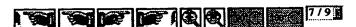




ritted closely together as shown, or may he spared around list rane, with separators used between them to meistain the desired sparing. The resident of columns amplayed will depend upon column characteristics and the meistains of construction. For example, the elemberness ratio of the column may be warled widely, sed the column sods may be round, flat, fluxed or hanged. The preserved construction is a thin, elember column with nomined axis, from to wowe within the rance shaped to the commisses of the column code. Materials which may be estimated to the commisses of the column code. Materials which may be estimated to the commisses are quested and low alloy steels, chronical makes become set alone-shaped as stables are quested and low alloy steels, see planghor broade, because stables stools, various copper been allow, such as planghor broade, because support, the high stable allows and other similar externals providing actificatory technologic, various copperation. Typically, the individual columns are of long revises plant cross-section, with the midth bring greater than the thickness, and accumple so that the wider face of the notumns is somet to the almost or the shaft. Thus, with surfacient consponential looking, the columns backle, and tend about the axis hering the loast sometic of inertia, e.g., outsattly may frue the shaft 18.

For example, a group of columns 0.167-inch thick by 0.835-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.2.8.I Also steel, quantiled and draws at 775°F. Bush column was found to require a critical compression loading of 550 pounds in order to bushle the entumn. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, therefore F<sub>0</sub> is the critical buckling load and point 0 represents the load and deflection at which the airces in the extress fibers of the delarm exceed the yield point of the untertal. Theoretically, the shape of this spring observativistic curve is described by earts 04'AlO. Actually, this curve is described by GAIC due to friction is the system. Poteta A and 2 represent typical working limits, which, of course, say he varied according to the application for which the spring is designed. For example, where a large custor of flexing system are not embicipated, a vertice stress just below the yield points may be used, while with a great number of flexines, the working stress may be held to less than the emburace limit of the seterial of construction. In the above-maritimed teats, the lateral deflection was limited to

- 7 -





approximately one just, at which the longitudinal deflection was approximately 0.825 inches. From more deflection to the assumes deflection, the \$50-yourd loading was found to be substantially constant.

In emother test a spring durine was built, as down, employing 80 columns, each having a critical buckling load of 1850 possés. The interal definition was limited between 0 and about 1.00 inches by empropriately positioning the steps. One empressional loading, the spring element bucklet at emeaturability 25,000 possés and frum a longitudinal deficacion of 0.05 inches (buckling) to stook 0.15 inches the load rearrant substantially at 85,000

Or course, in contents a spring elevant as above it is attendance to obtain the greatest possible value of longitudinal defication for specified values of lateral deflection and critical bushing load, while unintelling the atmosphere is the column at a cafe level. The preferred columns, therefore, are landanted, as shown in Figures 13 and 2, with maintain flat contents

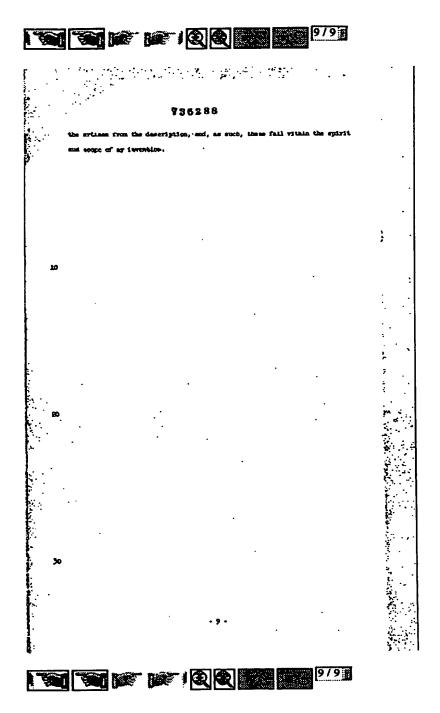
In the operation of the shows expecting tool for setting a liner in well excise, the mede-up tool is lowered into the well as sectioned shows, with the area 22 in the rejected position. Then the tool is at the desired level, the sail taking is revolved. The friction number by engages with the wall of the easing and prevents thinkle hi from revolving. But several revolutions of the toting, knear shoulder 18 is novel meantly by differential server 39 to bushle opering elevents 37 which has a predefermined critical bushling lead. This lead is transmitted upwerful against the lower cal of expender 18, and its tapered surface is engaged with the tapered surface on the inside of the even 22 to urgs the turn outsurdly with a substantially constant force proportional to the critical bushling lead of the spring element. Subsequently, the expending tool is passed through the liner to expend it in the casing in the sector described brainsfore.

the foregoing description of a preferred embeliant of my invention has been given for the purpose of examplification. It will be understood that verious medifications in the details of construction will become apparent to

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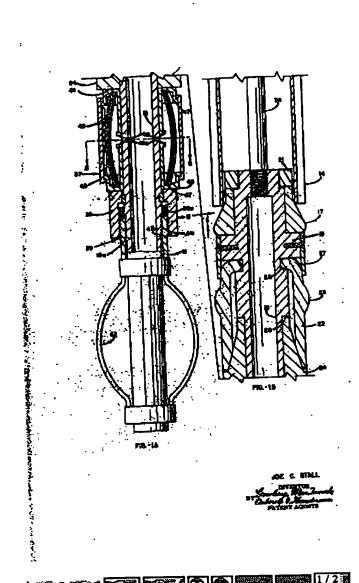
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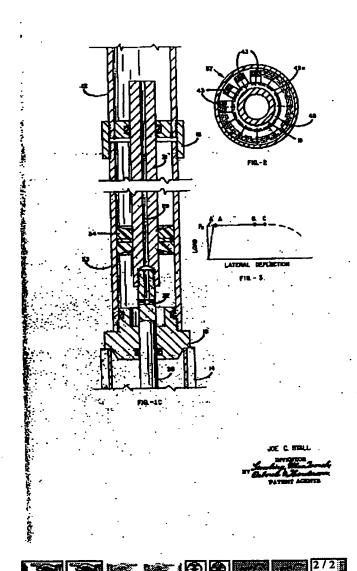




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